



## THE BLOOMBERG WAY

A Guide for Reporters and Editors

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species, and maintaining temperature of an SiC seed crystal in a second zone in the vessel at a temperature where condensation of said vapor species can occur;

during an entire growth period, maintaining said seed crystal and said source material temperatures constant and only adjusting the pressure of said inert gas to change the growth rate of the single crystal; and

lowering said seed crystal and said source material temperatures directly back down to room temperature after said entire growth period.

13. The method according to claim 12, wherein said entire growth period includes:

a preliminary period where pressure is first lowered to grow a base of the single crystal, and

a main period where pressure is lowered further after said preliminary period to grow a remaining portion of the single crystal.

14. The method according to claim 12, wherein said temperatures of the seed and source material are temperatures that avoid super saturation and are sufficient to prevent the formation of macrodefects that significantly adversely affect a crystal lattice of the single crystal.



15. A method of growing a silicon carbide single crystal in an inert gas environment in a vessel, comprising the steps of:

raising temperature inside a first zone of the vessel with a source material that enables sublimation of said source material into a vapor species, and maintaining temperature of a second zone of the vessel with a seed crystal that enables condensation of said vapor species;

maintaining said source material and said seed crystal temperatures constant throughout an entire growth period of the single crystal; and

changing the growth rate of the single crystal during the growth period only by adjusting the pressure of the inert gas,

said entire growth period being defined from when pressure is first reduced to permit transport of source material to said seed crystal and to the time when said pressure is increased to end growth of the single crystal.

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16. The method according to claim 15, wherein said temperatures of the seed and source material are temperatures that avoid super saturation and are sufficient to prevent the formation of macrodefects that significantly adversely affect a crystal lattice of the single crystal.

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- 17. A method of growing high quality silicon carbide single crystals by physical vapor transport in an inert gas environment in a vessel, comprising the steps of:
  - (a) preheating including the substeps of:
    - (i) raising the pressure of the inert gas to a non-transport pressure that prevents mass transport of source material to the seed crystal,
    - (ii) heating a SiC source material to a sublimation temperature, and
    - (iii) maintaining an SiC seed crystal at a condensation temperature;
- (b) stabilizing including the step of holding said seed crystal and said source material temperatures and said non-transport pressure for a duration sufficient to establish thermal equilibrium in the vessel;
  - (c) preliminary growth including the steps of:

lowering pressure of said inert gas to a first pressure without changing any temperature, and

holding said first pressure including the steps of

preventing macrodefect formation on a seed crystal surface, and growing a base of the single crystal on the seed crystal at a first growth rate;

- (d) main growth including the step of further lowering the pressure of the inert gas to a second pressure for continuing the growth of the single crystal at a second growth rate that is faster than said first growth rate;
- (e) growth termination including the step of increasing the pressure to stop transport of source material to said seed crystal;

- (f) cooling including the step of decreasing the temperature inside the vessel from said source material and said seed crystal temperatures; and
- (g) opening said vessel including the step of changing the pressure to equalize the pressure relative to pressure external to the vessel.

18. The method according to claim 17, wherein said step (c) lasts for at least

0.5 hours.

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19. The method according to claim 17, further comprising a degassing step before step (a) where temperature inside the vessel is raised above room temperature but

below said seed crystal temperature, and pressure is decreased to a level sufficient to

remove air and contaminants from said vessel.

20. The method according to claim 17, wherein said step (d) further includes the step of introducing doping gases.

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21. The method of claim 17, wherein said step (c) is maintained for approximately three hours and said step (d) is maintained for at least approximately 3 hours.

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22. An apparatus for growing silicon carbide single crystals, comprising:

a vessel holding a SiC seed crystal in one zone and SiC source material within another zone in the vessel;

a means for controlling the temperature within the vessel so that said seed crystal is maintained at a constant temperature  $T_{\text{seed}}$  and said source material is maintained at a constant temperature  $T_{\text{source}}$  where  $T_{\text{source}} > T_{\text{seed}}$ , said temperatures being held constant throughout an entire growth period of the single crystal; and

means for controlling the pressure of mert gas within the vessel to adjust the pressure to control a growth rate of the single crystal.

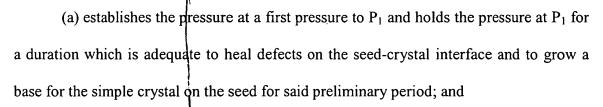
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23. The apparatus according to claim 22, wherein said entire growth period includes a preliminary period for growing a base of the single crystal and a main period for growing a remaining portion of the single crystal, and

wherein said means for controlling pressure:

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- (b) after growing said base, further reduces the pressure from  $P_{\theta}$  to a second pressure  $P_2$  to continue growing the single crystal during the main period.
  - 24. The apparatus of claim 23, wherein  $P_1$  is selected from the range of approximately 10 to approximately 50 Torr, and  $P_2$  is preselected to be less than about 10 Torr.

25. The apparatus according to claim 23, wherein said means for controlling the pressure holds the pressure at P<sub>2</sub> for said remaining period of the entire growth period, until it raises the pressure to stop the growth.

26. The apparatus according to claim 23, wherein said preliminary period step of growing said base lasts at least 0.5 hours.

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- The apparatus according to claim 22, wherein said means for controlling the pressure first raises the gas pressure to a pressure  $P_{\theta}$  that blocks transport of the source to the seed before the temperatures  $T_{\text{seed}}$  and  $T_{\text{source}}$  are obtained, and provides a period of stabilization by holding pressure at  $P_{\theta}$  while said means for controlling the temperature maintains  $T_{\text{seed}}$  and  $T_{\text{source}}$  before the means for controlling the pressure decreases the pressure to begin growth of the crystal.
- 28. The apparatus according to claim 22, wherein said means for controlling the pressure and said means for controlling the temperature, at the end of the growth period, respectively raises the pressure to stop the growth of the single crystal and lower the temperatures of the seed crystal and source material down to room temperature.
- 15 29. The apparatus according to claim 22, wherein, before the growth period, said means for controlling the temperature raises the temperature inside the vessel above room temperature but below T<sub>seed</sub>; and

said means for controlling the pressure lowers the pressure to a predetermined pressure  $P_{degas}$  to remove air and contaminating particles from the vessel.

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30. A method of growing a silicon carbide single crystal on a silicon carbide seed crystal in an inert gas atmosphere in a vessel, comprising the steps of:

establishing the seed crystal temperature to a growth temperature  $T_{\text{seed}}$  and establishing the temperature of source material to a growth temperature  $T_{\text{source}}$  that is higher than  $T_{\text{seed}}$  to define a thermal gradient therebetween;

maintaining constant seed temperature and constant source temperature throughout substantially the entire growth period of the single crystal, said entire growth period beginning when the seed crystal and source material reach  $T_{\text{seed}}$  and  $T_{\text{source}}$ , respectively; and

changing the pressure of the inert gas without changing said temperatures and without moving either said seed crystal or said source material or both by mechanical means to change a thermal gradient between  $T_{\text{seed}}$  and  $T_{\text{source}}$  during the entire growth period to control the growth rate of the single crystal.